

CHARACTERIZATION AND EVALUATION OF VARIOUS MATERIALS FOR AUTOMOBILE COMPONENTS

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ABSTRACT

This paper describes about various material (En19, En24, SAE8620 and AL6061 T6) can be used for manufacturing of automobile components in place of currently used components. Experimental studies were conducted to study their characteristics and analyse the mechanical properties. This can be done by performing hardness, impact, tensile, torsion, fatigue and double shear tests for finding of mechanical properties, and for the studies of composition, EDX analysis is performed.

KEYWORDS: Materials, Automobile, Mechanical Properties, Specimens & Testing

Received: Jun 25, 2017; **Accepted:** Jul 13, 2017; **Published:** Jul 18, 2017; **Paper Id.:** IJMPERDAUG201717

INTRODUCTION

The Indian auto components industry has experienced 7% of Gross Domestic Product (GDP) over the last few years, because of a stable government framework. With increased purchasing power, large domestic market, and constantly developing infrastructure that made India a better place for investment [1]. For the production of automobile components, it required a very wide variety of raw materials including Iron (Fe) into steel; aluminium; glass; plastics; rubber and special fibers [2]. Firstly, raw materials are mined from the earth, after that it is processed into materials. So that, auto manufacturers can use in the production of automobiles.

Currently, automotive industry is doing research and experiments into reduce the overall weight of the car, improve its safety and crash worthiness while cost is less. Steel is the best choice material from the beginning of automobile manufacturing. But now days use of aluminium is increased instead of steel, especially in body parts and bumpers of vehicles, because of its malleability, light weight nature and good shock absorbing property [3]. Many researchers concluded that new composite materials have better properties and suitable in performance. But their casting, machining, fabrication and heat treatment process may alter the properties. A vehicle is assembly of many components like transmission, axle beams, steering knuckle, chassis, leaf spring, body parts and engine components. The details about which components is made of which materials, its methods and grade are shown in Table 1.

The main aim of this research is to find the alternative grade of materials, which are not used in the casting of particular components. This can be done by studying existing materials' chemical composition, their physical properties, micro-hardness and microstructure.

Table 1: Detailed about Material used in Automobile Components [4]

Name of the Part		Material Used	Method of Manufacture	Material Grade
Engine Components	Cylinder	Cast iron, alloy steel	Casting	En18, En19, SAE4140, 42CrMo4, SCM440, En198, 39Cr5, SAE1541, SAE1548, 40CrMo4H, 2CrMo, C38+N2, 38MnSiVS5, 38MnS6, 46Mn5, CMA-1, 38MnSiVS5, C70S6, S48C, S48CS1, AW6060, AW6082, A356
	Cylinder head	Cast iron, aluminium alloy	Casting, forming	
	Piston	Cast iron, aluminium alloy	Casting, forging	
	Piston ring	Silicon cast iron, chrome steel	Casting	
	Piston pins	Steel	Forging	
	Valves	Special alloy steels	Forging	
	Connecting rod	Nickel alloy steel, aluminium, titanium, iron	Forging	
	Crankshaft	Alloy steel, SG iron	Forging	
	Crankcase	Aluminium alloy, steel, cast iron	Casting	
	Cylinder liner	Cast iron, nickel alloy steel	Casting	
Transmission	Gear box	Steel, Aluminium	Casting, Forging	SAE8620, SAE8625, SAE8627, ETN22, ETN25, ETN27, 16MnCr5, 20MnCr5, SCM420, SAE4120, En353, En354, SAE8822H, 815M17
	Propeller shaft			
Axle Beams		Cast iron, Cast Aluminium, Forged steel	Forging	SAE1045M, 709M40, SAES322, 40Cr4C, 41CRS4, S58C, SS4510/HMnTi, 30MnVS6+Ti, En15A, SAE1041, SAE1541
Steering Knuckle		Aluminium alloy, Steel, Iron	Forging	SAE4135, SCR440, SAE5137H, SAE11v37, ASTM A356-T6, A536, En47
Chassis		Spring Steel		SS316, AA5049, AA5454
Doors, closures, outer panels		Steel, Aluminium	Forming, Forging	AA5182

EXPERIMENTAL DETAILS

Materials Used

The auto-components are made by different type of materials, such as steel and aluminium. The material which is selected for the testing is SAE8620, En19, En24 and Al6061 T6.

In this paper, SAE8620 is used because of its capability of wearing resistance and toughness. En19 is used because of its ductility, shock resistance and resistance in very high loading. En24 is used because of its strength, ductility, and wear resistance. AL6061 T6 is used because of its strength, toughness, non-corrosive and applications where, heat transfer is required. T6 (temper 6) means a solution, heat treated and artificially aged.

Table 2: Physical Properties of Specimen Materials [5]

Properties	En19	SAE8620	En24	AL6061 T6
Density (g/cm ³)	7.8	8.08	7.85	2.7
Melting Point (°C)	1540	1425	1427	588
Tensile Strength (MPa)	850	820	745	310
Yield Strength (MPa)	680	590	470	275
Elongation (%)	13	22	22	12-17

Table 3: Standard Chemical Composition of Materials[6][7]

Elements	En19	SAE8620	En24	AL6061 T6
Aluminium	-	-	-	95.8 - 98.6
Carbon	0.36 - 0.44	0.17 - 0.23	0.35 - 0.45	-
Copper	-	-	-	0.15 - 0.4
Chromium	0.9 - 1.2	0.9 - 1.2	0.90 - 1.40	0.04 - 0.35
Nickel	-	-	1.30 - 1.80	-
Iron	96.7 - 97.8	96.8 - 97.9	96.7 - 94.8	0.7 max
Manganese	0.7 - 1	0.6 - 0.95	0.45 - 0.7	0.15 max
Magnesium	-	-	-	0.8 - 1.2
Molybdenum	0.202	0.25 - 0.35	0.20 - 0.40	-
Titanium	-	-	-	0.15 max
Phosphorus	0.035 max	0.04 max	0.04 max	-
Zinc	-	-	-	0.25 max
Sulphur	0.04 max	0.04 max	0.04 max	-
Silicon	0.1 - 0.4	0.1 - 0.4	0.10 - 0.35	0.4 - 0.8
Other, each	-	-	-	0.05

Testing Methodology

Hardness Testing –Rockwell hardness test is performed to determine the hardness of the materials. According to ASTM E-18 standards, hardness of materials is tested on A, B and C scale with a load of 60, 100 and 150kgf respectively, in a dwell time duration of 5 seconds. For En19, En24, SAE8620 materials is tested on A and C scale with a diamond indenter and for AL6061, T6 is tested on A and B scale with a 1/16" ball indenter. The result of hardness is average of 6 trials of each specimen.

**Figure 1: Hardness Testing Specimens Dimension**

Impact Testing – Izod and Charpy test is conducted as per ASTM E-23 standards to determine the toughness or impact strength of the materials. It involves the specimen to be struck by the impact strength of 30kg (300J) with a speed of 5m/s for Charpy test and for Izod test, the impact strength is 16.4kgm (164J). The pendulum hammer is raised as per the standards for the Izod and Charpy test depending upon the type on specimen to be tested. The pendulum converts its potential energy into kinetic energy, just before it strikes the specimen. This test shows whether the material is ductile or brittle in nature.

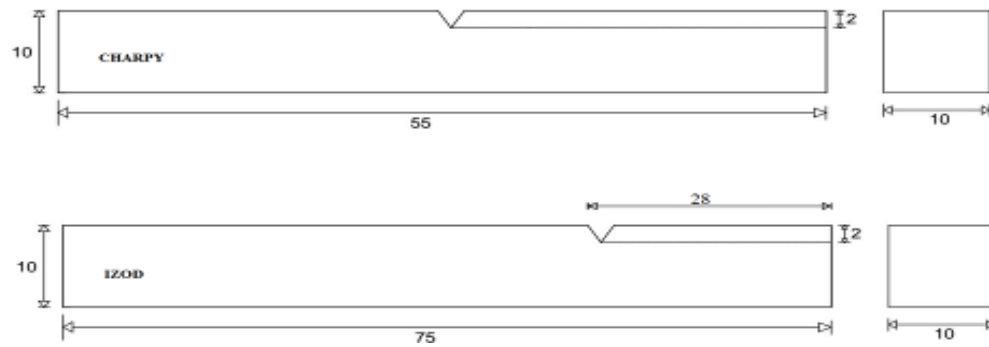


Figure 2: Impact Testing Specimens Dimension

Double Shear Testing – The most common use of a shear testing is to determine the maximum shear strength of the materials. Universal testing machine is used for performing shear, compression and tension. The force applied in shear test is parallel to the two contact surface whereas, in tension and compression, they are perpendicular to the contact surfaces.



Figure 3: Double Shear Testing Specimen Sizes and Materials

Fatigue testing – Fatigue test is the method for determining the behaviour of materials under fluctuating loads. A cyclic load is applied to the specimen until it breaks in order to measure the fatigue resistance of the material. The fatigue life is indicated by the number of cycles to failure, N . The fatigue testing is conducted by using a rotating beam fatigue tester. The machine can record the number of cycles to failure with the counter.

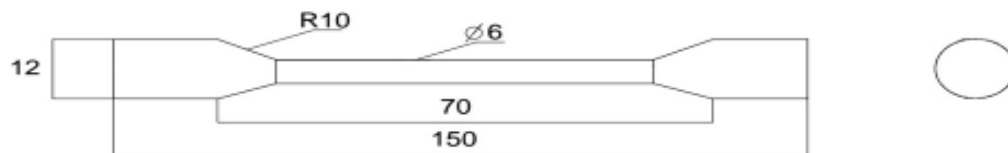


Figure 4: Fatigue Testing Specimens Dimension

Tensile testing – Tensile testing is most common methods for determining materials properties. It is also known as tension testing, is a fundamental materials science test, in which, a specimen is subjected to a controlled tension until failure. The tensile test has been carried out on computerized Universal Testing Machine (UTM) of 1000 KN capacity.



Figure 5: Tensile Testing Specimens Dimension

Energy Dispersive X-ray spectrometry – EDX uses a focused beam of high energy electrons to generate a variety of signals at the surface of solid materials, which is present in Scanning Electron Microscope (SEM). It is an analytical technique used for chemical composition and elemental analysis

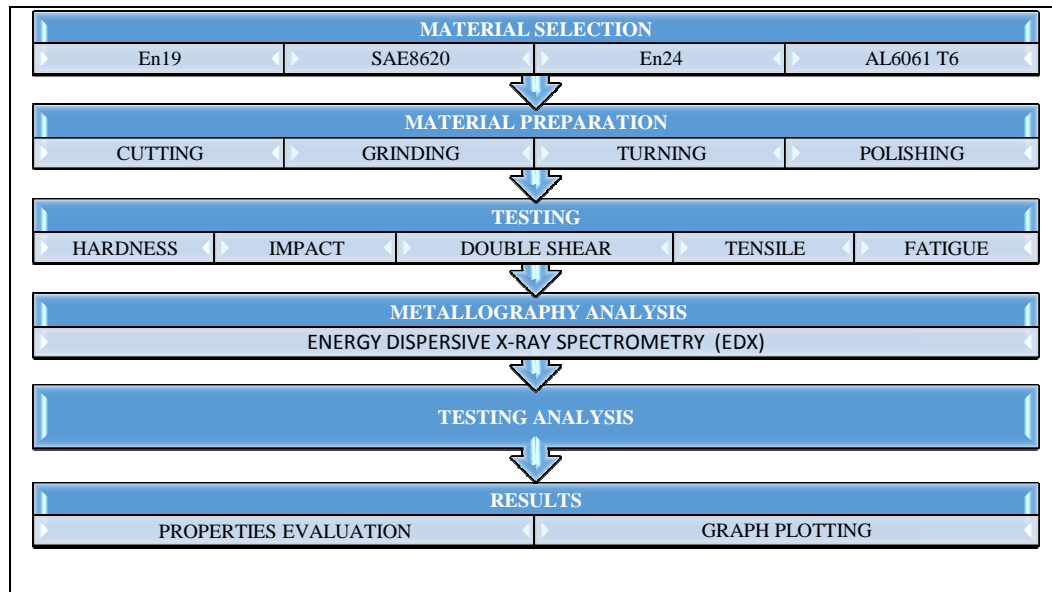


Figure 6: Flow Chart of Experiment

RESULTS

Mechanical Testing

Hardness test – The resistance to indentation value of specimens and materials is shown in Figure 7. Rockwell hardness machine test results is tabulated in Table 4 and compared by Table 5. This shows, which specimens are harder than other materials which are selected by Table 1, after studies of components. Figure 8 shows the specimens after hardness test.

Table 4: Rockwell Hardness Test Results

Specimens	Unit		
	HRA	HRC	HRBw
En19	64.45	28.75	-
En24	61.23	21.40	-
SAE8620	57.66	17.86	-
AL6061 T6	27.7	-	14.18

Table 5: Comparing Hardness Materials Properties[8]

Materials	Unit		
	HRA	HRC	HRBw
SAE1548	59	17	-
En353	72	43	-
SAE1541	50	12	-
En47	58	14	-
AA5454	24	-	12
AA5182	21	-	11

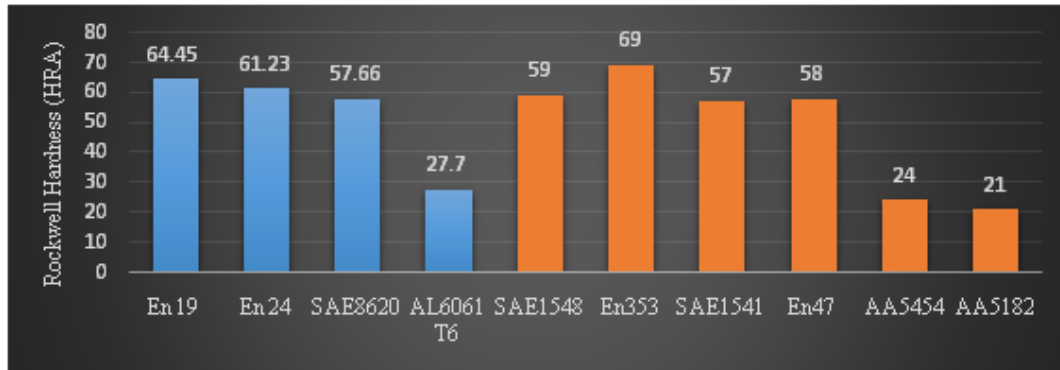


Figure 7: Rockwell Hardness Test



Figure 8: Hardness Test Specimens

Impact test –The resistance of material to resist an impact or sudden load applied is impact strength. The results measured in terms of energy (joules) are shown in Table 6 and the comparing material which is taken from Table 1; those values are shown in Table 7. The graph in Figure 9 shows the Izod and Charpy values of both Table 4 and Table 5. Figure 10 and Figure 11 shows the specimens after performing test.

Table 6: Impact Test Results

Specimens	Izod Testing (Joules)	Charpy Testing (Joules)
En24	162	210
En19	46	90
SAE8620	60	140
AL6061 T6	30	100

Table 7: Impact Test Value of Comparing Materials [5]

Materials	Izod Value (Joules)	Charpy Value (Joules)
SAE1548	85	41
En353	115	50
SAE1541	80	39
En47	27	18
AA5454	29	70
AA5182	23	65

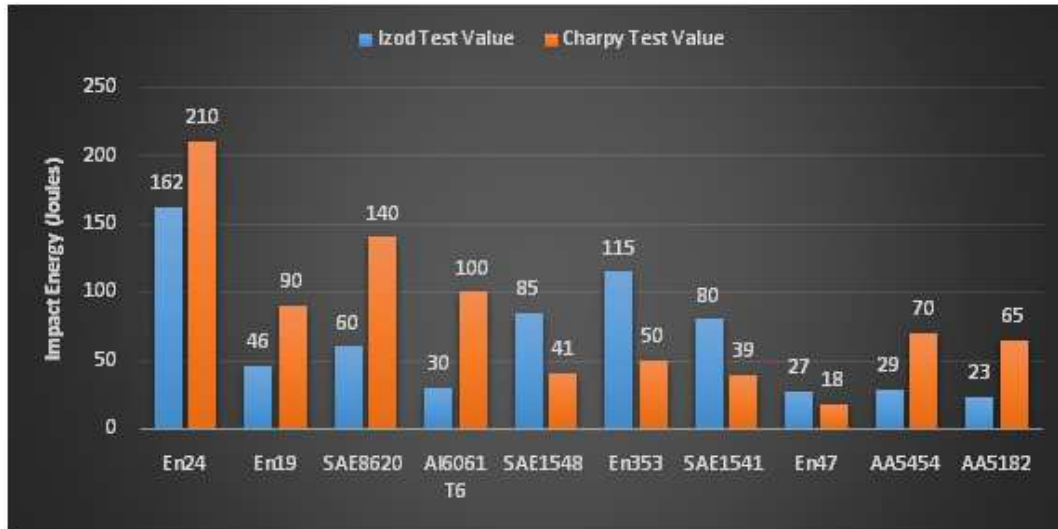


Figure 9: Impact Test Value



Figure 10: Izod Test Specimens



Figure 11: Charpy Test Specimens

Tensile test –Table 8 shows the results of tensile test of specimens done on UTM machine, and Table 9 shows comparing material properties taken from Table 1. Figure 13 is generated by computerized UTM machine showing the relationship between Load (kN) and Displacement (mm). Figure 12 shows the specimens after test.

Table 8: Tensile Test Results

Properties	SAE8620	En19	En24	Al6061 T6
Ultimate Tensile Load (kN)	178.900	220.600	134.900	80.300
Ultimate Tensile Strength (MPa)	878	1110	697	950
Displacement at Ult. Load (mm)	29.100	46.300	46.400	30.200
Maximum Displacement (mm)	37.600	54.600	57.300	42.400
Percentage Elongation (%)	17.778	68.550	27.210	21.294
Breaking Load (kN)	143.000	191.600	108.200	62.700
Breaking Stress (kN/mm ²)	0.702	0.964	0.559	0.742
Yield Load (kN)	157.100	178.200	75.900	47.200
Yield Strength (MPa)	771	897	392	558
Displacement at Yield Load (mm)	11	24	2	1

Table 9: Comparing Materials Properties[5]

Properties	SAE1548	En353	SAE1541	En47	AA5454	AA5182
Ultimate Tensile Load (kN)	167.440	165.404	169.221	170.494	66.161	106.876
Ultimate Tensile Strength (kN/mm ²)	658	650	665	670	260	420
Percentage Elongation (%)	10	12	8	23	14	4
Yield Load (kN)	137.413	68.706	92.881	105.604	45.804	100.515
Yield Strength (MPa)	540	270	365	415	180	395



Figure 12: Tensile Test Specimens

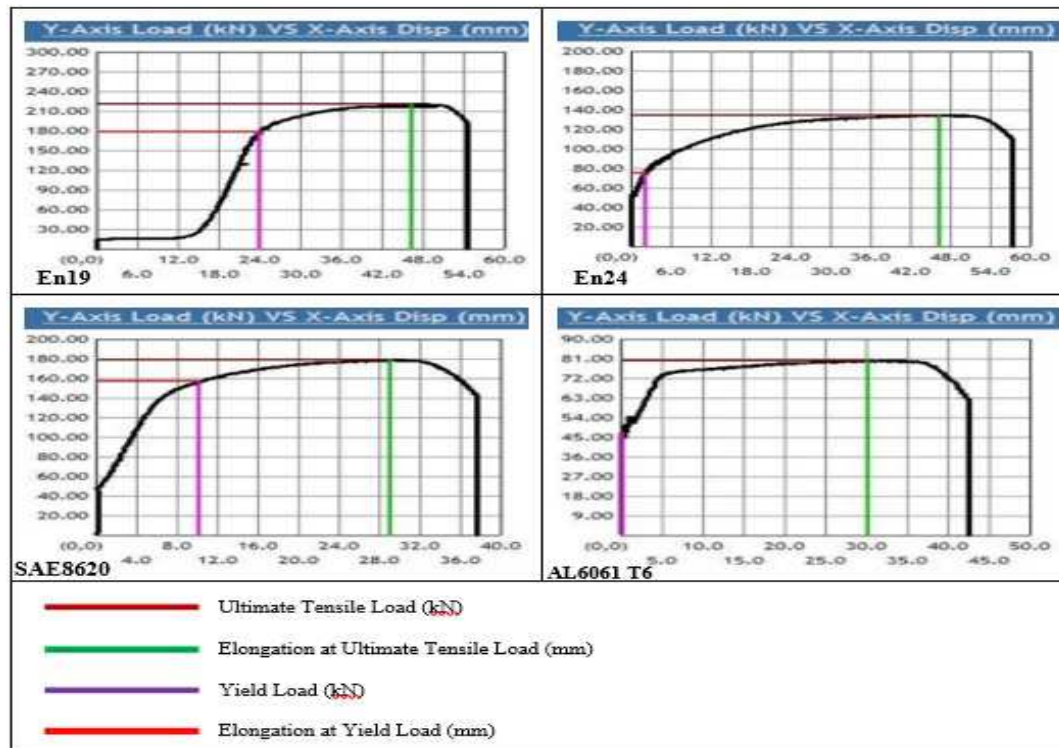


Figure 13: Tensile Test Results

Fatigue test –A method for determining the behaviour of materials under fluctuating loads. The process of fatigue consists of 3 stages shown in Figure 15 i.e. Initial fatigue damage leading to crack nucleation and crack initiation. Then, Progressive cyclic growth of a crack (crack propagation) until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied. Finally, sudden fracture of the remaining cross section [9]. Figure 14 shows the relation between stress amplitude and number of cycles. Table 10 shows the results of test. Figure 16 shows specimens after fracture due to loads.

Table 10: Fatigue Test Results

Properties	En24	EN19	SAE8620	AL6061 T6
Total Weight (N)	40.221			
Number of Cycles (rpm)	6245	6899	9061	4010

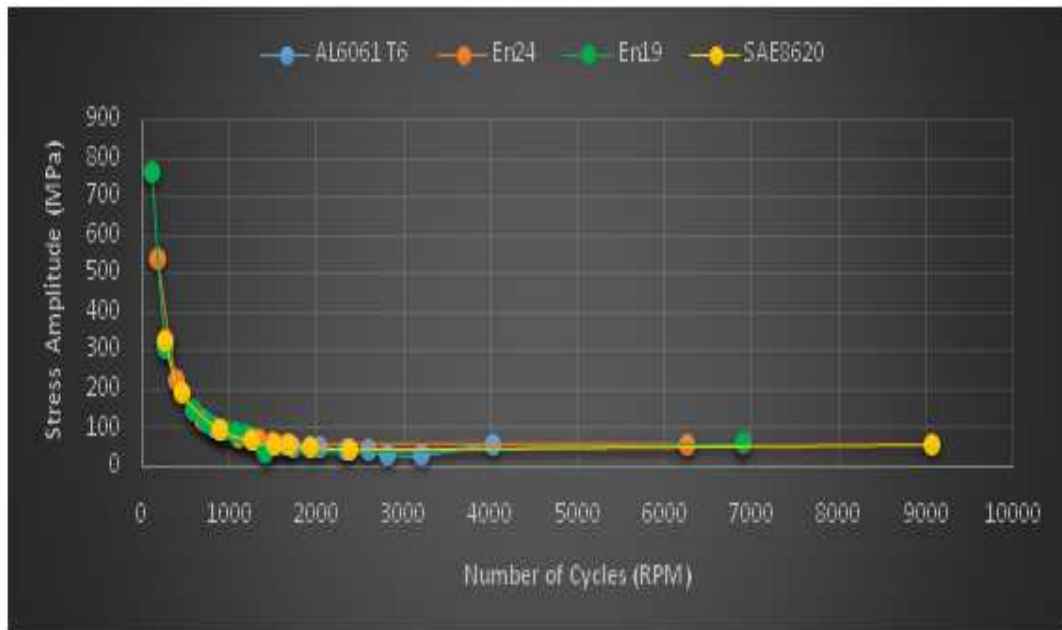


Figure 14: Fatigue Test Results

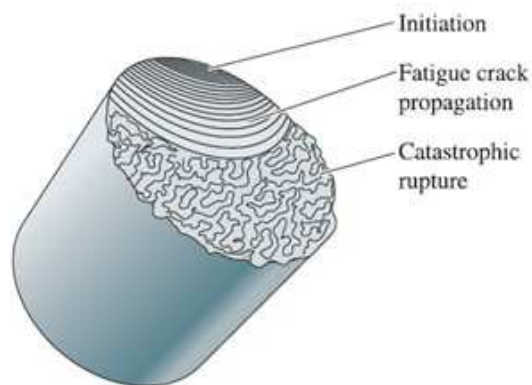


Figure 15: Schematic Representation of a Fatigue Fracture Surface



Figure 16: Fatigue Test Specimens

Double shear test – Figure 17 shows the relation between load (kN) and displacement (mm) of specimens. Table 8 and Table 9 shows the maximum shear strength of materials. Figure 18 shows the specimens after fails to withstand shear force.

Table 11: Double Shear Test Results

Specimens	Maximum shear strength (N/mm ²)
SAE8620	404.3559
En19	616.1613
En24	428.4247
AL6061 T6	173.9537

Table 12: Comparing Materials Properties [5]

Materials	Maximum shear strength (N/mm ²)
SAE1548	357
En353	421
SAE1541	343
En47	540
AA5454	160
AA5182	150

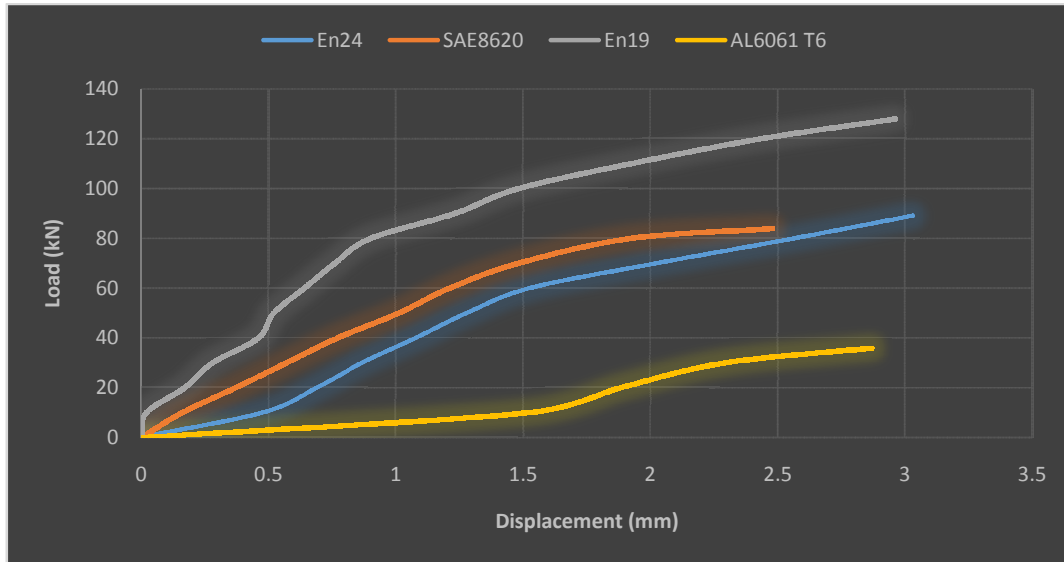


Figure 17: Double Shear Test Results



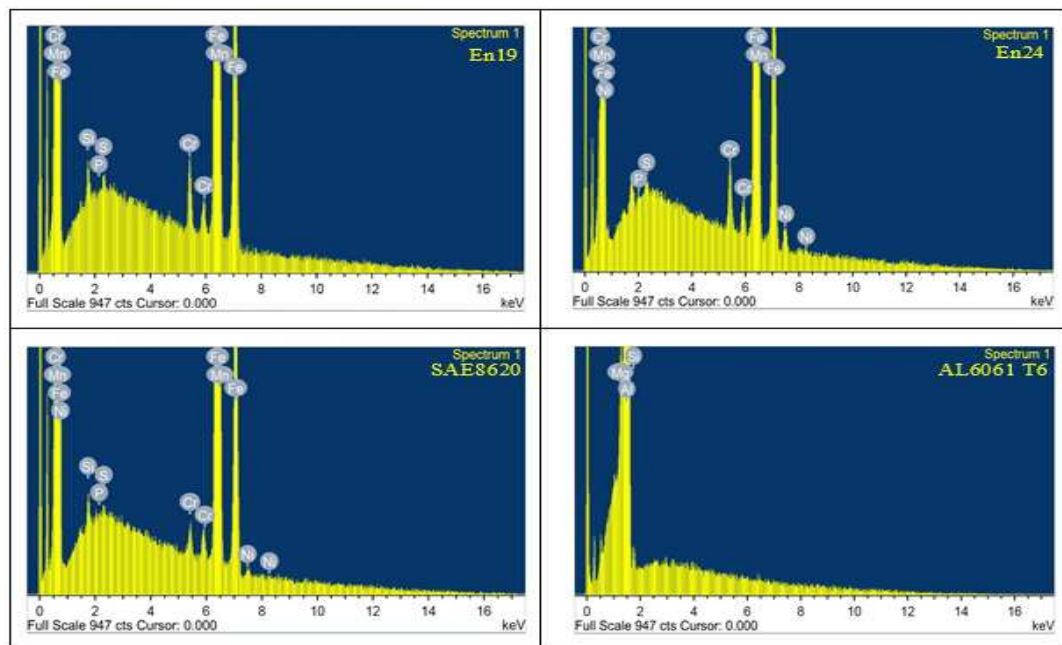
Figure 18: Double Shear Test Specimens

Microstructure Analysis

EDX – The chemical composition of the specimens traced in EDX analysis are tabulated in Table 13 and the peak of elements can be seen in Figure 19.

Table 13: Chemical Composition of Materials Traced in EDX Analysis

Element	En19	SAE8620	En24	Al6061 T6
Manganese	0.72	-	-	-
Phosphorus	0.01	0.10	0.09	-
Sulphur	0.17	0.11	0.12	-
Silicon	0.42	-	0.39	0.45
Nickel	-	1.44	0.50	-
Chromium	1.35	1.24	0.58	-
Iron	97.33	96.21	97.49	-
Copper	-	-	-	-
Magnesium	-	-	-	0.40
Titanium	-	-	-	-
Zinc	-	-	-	-
Aluminium	-	-	-	99.15

**Figure 19:Elemental Composition of Specimens**

CONCLUSIONS

In these experiments, the tests were conducted to find the alternatives materials that are not used currently in that components manufacturing. After evaluating the results, En19 is found to be the best alternative for manufacturing of cylinder in engine components as well as AL6061. T6 can also be used because; it has high ultimate strength and yield strength, at the same time, low density. For Piston, SAE8620 has high fatigue life and more toughness as shown in graph due to presence of nickel. Connecting rod and Crankshaft have high strength. So, En24 is good for manufacturing. En19 also has good wearing properties as revealed in the paper, and it is easy to shape, so, it is good for gears manufacturing. For Propeller shaft, SAE8620 is the best because, it can take a lot of fatigue. An Axle Beams should have high strength and low density. So, En24 is better than, as well as SAE8620 can be used. En19 is better for Steering Knuckle because, it has high tensile strength and toughness. Chassis has to bear a lot of loads, and doors of the vehicle has to resist more impact, at the same time, both have to be light-weight, so, AL6061 T6 is the best replacement for the manufacturing.

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